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WESTERN SPRUCE BUDWORM SUPPRESSION AND EVALUATION PROJECT USING CARBARYL--1977

Santa Fe National Forest
and
Jemez Pueblo Indian Reservation
New Mexico

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ABSTRACT

Egg mass densities and defoliation of new foliage both increased significantly in the treated area in 1982. Apparent top-kill of poles and sawtimber was less in the treated area; the treatment appears to have prevented permanent tree damages to the overstory so far. Apparent top-kill of seedlings and saplings was greater in the untreated area; mortality was at the same level in both areas. Possible future infestation scenarios and future sampling plans are discussed.

INTRODUCTION

In 1977, a suppression project was conducted to evaluate the prolonged effects of an insecticide treatment on a building western spruce budworm, Choristoneura occidentalis Free., outbreak to determine if a "population reduction strategy" was a viable alternative. Carbaryl (Sevin 4 oil[1]) was aerially applied to 37,450 acres of forested land in an isolated mountain range on the Santa Fe National Forest and the Jemez Pueblo Indian Reservation. Objectives of the project were to: (1) Suppress the budworm population to such a low level that mating becomes less likely, parasites and predators become more significant in regulating the population, and density-independent factors, such as weather, keep the budworm population below an economically damaging level; (2) evaluate the effectiveness of suppression for a 2-year period in the treated area and a comparable untreated check area (37,398 acres); and (3) evaluate and compare annual defoliation and tree damages in the treated and untreated areas.

The application phase of the project was successfully completed in 1977 (Parker et al. 1978).[2] Criteria established to show treatment success were: (1) Reducing the budworm larval density by an average of 90 percent and (2) obtaining an egg mass density of less than 1.5 new egg masses per square meter of foliage. The 1976-77 budworm generation was reduced by an average of 93.1 percent, compared with a 44.5 percent reduction in the untreated area. The adjusted budworm mortality, using Abbott's formula, was 87.5 percent. One larva per 100 buds of Douglas-fir remained 14 days following treatment. The average density of new egg masses was 1.6 per square meter in the

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[1] Union Carbide Corporation trade name for carbaryl insecticide.
[2] Parker, Douglas L., Robert E. Acciavatti, and Eugene D. Lessard. 1978. Western spruce budworm suppression and evaluation project using carbaryl. Progress Rep. No. 1, USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 78-11. 136 pp.

treated area and 9.9 per square meter in the untreated area. Although an average of 84.1 percent of the budworm larvae were in the fifth and sixth instars and 0.3 percent were pupae at the time of treatment, defoliation was considerably lower than that recorded in the untreated area: Treatment area--26.5 percent for Douglas-fir and 37.0 percent for white fir; untreated area--40.8 percent for Douglas-fir and 61.3 percent for white fir.

Sampling for larval densities, number of egg masses, and defoliation on the plots was done in 1978 and 1979 to determine whether suppression effects continued. Larval and egg mass densities and defoliation remained at low levels for both years in the treated areas, and increased in the untreated area.[3] [4]

Sampling for egg mass densities, defoliation and mortality, and apparent top-kill of seedlings and saplings was continued in 1980[5] and 1981.[6] Egg mass densities and defoliation remained at low levels in the treated areas and continued to increase in the untreated areas. Mortality and apparent top-kill of poles and sawtimber were also sampled in 1981.[6] Apparent top-kill was greater in the untreated area. In 1982, egg mass densities, defoliation, mortality, and apparent top-kill were sampled. Results are presented in this report.

METHODS

Sampling Locations

The treated and untreated areas were divided into six subunits in 1977 (figure 1). In each subunit, 25 permanent plots (3-tree cluster) were

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[3] Parker, Douglas L., Eugene D. Lessard, and Iral Ragenovich. 1979. Western spruce budworm suppression and evaluation project using carbaryl. Progress Rep. No. 2, USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 79-8. 109 pp.

[4] Parker, Douglas L., and Iral R. Ragenovich. 1980. Western spruce budworm suppression and evaluation project using carbaryl. Progress Rep. No. 3, USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 80-1. 56 pp.

[5] Ragenovich, I. R., and D. L. Parker. 1981. Western spruce budworm suppression and evaluation project using carbaryl, 1980. Progress Rep. No. 4, USDA Forest Serv., Southwestern Reg. R-3 81-9. 43 pp.

[6] Telfer, W. G, I. R. Ragenovich, and T. J. Rogers. 1982. Western spruce budworm suppression and evaluation project using carbaryl, 1981. Progress Rep. No. 5, USDA Forest Serv., Southwestern Reg. R-3 82-7. 18 pp.

established, as uniformly as possible, throughout each subunit along roads and trails. Each plot was assigned a unique number. Data were collected on these permanent plots from 1977 to 1979. In 1980, 12 of the original 25 permanent plots in each subunit were used for data collection. The same 12 subunits were again sampled in 1981 and 1982.

Egg Mass Densities

Sampling Design for Egg Masses

In late July, two branches (70 cm in length) were cut from opposite sides of sample trees on permanent plots. The length and width of each branch were used to calculate foliated branch area.

Foliage from all branches was examined under ultraviolet light for egg masses. Needles bearing egg masses were classed as from current year's foliage, or a previous year, and kept separate in labeled pill boxes. New and old egg masses were separated under a stereomicroscope. All egg masses on current year's foliage were classed as new, and their characteristics formed the basis for aging those egg masses found on the previous year's foliage.

Analysis of Egg Mass Density Levels

Egg mass densities were expressed as number of new egg masses per square meter (1,550 square inches) of foliage. Subunit and treatment level means and standard errors were computed by the following equations.

Subscripts:

i = treatments	1 = spray, 2 = check
j = subunits	j = 1, 6
k = cluster	k = 1, 12
l = tree	l = 1, 3
m = branch	m = 1, 2

Cluster level:

$$X_{ijk} = \frac{\sum_{l=1}^{3} \sum_{m=1}^{2} \dfrac{\text{egg masses}_{ijklm}}{M^2 \text{ foliage}_{ijklm}}}{6}$$

where X_{ijk} is the mean for the k^{th} cluster in the j^{th} subunit in the i^{th} treatment.

Subunit level:

$$X_{ij} = \frac{\sum_{k=1}^{n} X_{ijk}}{12}$$

where X_{ij} is the mean for the j^{th} subunit in the i^{th} treatment.

$$S.E.\ x_{ij} = \sqrt{\frac{\sum_{k=1}^{n} X_{ijk}^{2} = \frac{\left(\sum_{j=1}^{n} X_{ijk}\right)^{2}}{n}}{n-1}}$$

where S.E. X_{ij} is the standard error of the mean X_{ij}.

Treatment level:

$$X_{i} = \frac{\sum_{j=1}^{6} X_{ij}}{6}$$

where X_i is the mean for the i^{th} treatment.

$$S.E.\ X_{i} = \sqrt{\sum_{j=1}^{6} S.E.\ X_{ij}^{2}}$$

where S.E. X_i is the standard error of the mean X_i.

Percent Defoliation

Defoliation on Douglas-fir was sampled on 12 clusters in each subunit. On all clusters, three codominant Douglas-fir, 30 to 50 feet tall, with relatively open-grown crowns, were sampled.

Sample branches consisted of four apical branches, 70 cm in length, taken from four quadrants at midcrown of each sample tree. From each of these branch samples, 25 new shoots were examined for current defoliation using the left side of 1 branch and the right side of another, and so on. Each new shoot was individually examined for defoliation and assigned an index value as follows:

6-class

Defoliation class %	Index value	Midpoint value %
0	0	0
1-25	1	12.5
26-50	2	37.5
51-75	3	62.5
76-99	4	87.5
100	5	100

Defoliation estimates were analyzed on a "per cluster" basis.

The following formula was used to determine the percent defoliation on a "per cluster" basis.

Percent defoliation =

$$\frac{n_1\,(12.5) + n_2\,(37.5) + n_3\,(62.5) + n_4\,(87.5) + n_5\,(100)}{N}$$

where n_1 = number of twiglets with index value 1
n_2 = number of twiglets with index value 2
n_3 = number of twiglets with index value 3
n_4 = number of twiglets with index value 4
n_5 = number of twiglets with index value 5

The previous formulas that were used to calculate egg mass densities by cluster, subunit, and treatment were used to calculate percent defoliation by cluster, subunit, and treatment.

Tree Mortality and Top-kill

Poles and Sawtimber

Data were collected from variable plots (20 BAF) established at the center subplot of each cluster plot. Apparent top-kill was determined visually. A tree was determined to be top-killed if there was no green foliage, no visible buds, and the stem appeared to be recently dead and not just defoliated. Two crew members had to agree the tree was top-killed before it was recorded as such. Mortality was recorded without determination of the causal agent.

Seedlings and Saplings

Tree damage data were collected at 5 locations in each of the treated and untreated subunits, for a total of 300 sample locations. At each location, a cluster of five permanent 1/100-acre fixed radius plots were sampled. Permanent 1/100-acre plots established in 1977 were used as the center plot, and four additional plots were located 100 feet from the center of the permanent plot in cardinal directions. Trees were recorded by species and condition (live, top-killed, dead). Trees with a diameter at breast height (d.b.h.) of less than 0.5 inches or less than 4.5 feet in height were considered seedlings. Saplings are 0.5 to 4.9 inches d.b.h. Pine and spruce trees also were recorded on each plot. Data were analyzed using the PEST computer program.[7]

RESULTS

Egg Mass Densities

Average egg mass densities on the treated and untreated subunits are shown in table 1. Average number of egg masses per square meter of foliage increased from 28.8 in 1981 to 38.2 in 1982 in the untreated area (figure 3). These densities are not significantly different at the 0.05 percent level; however, the western spruce budworm is obviously maintaining epidemic population levels in the untreated area. Acreage of defoliation may increase slightly, but most of the host-type is already infested; intensity of defoliation is expected to increase.

Average number of egg masses per square meter of foliage in the treated area increased from 6.1 in 1981 to 13.1 in 1982. This increase is significant at the 0.05 percent level. Egg mass densities increased on all treated subunits, except Red Top (table 1). Egg mass densities have been increasing in the treated area since 1979; they may continue to increase until epidemic levels similiar to the untreated area are reached, barring unforeseen natural mortality factors, such as weather.

Percent Defoliation

Average percent defoliation of new foliage decreased from 67.2 in 1981 to 61.3 in 1982 in the untreated area, and increased from 31.9 in 1981 to 44.9 in 1982 in the treated ares (figure 4). The increase in the

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[7] Acciavatti, R. E., and B. W. Geils. 1977. A user's guide to "PEST": A computer program for summarizing forest insect and disease damage surveys. USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 77-16. 45 pp.

treated area is significant at the 0.05-percent level (table 2). Barring unforeseen natural mortality, defoliation intensity levels in the treated area are predicted to increase in 1983, with the exception of the Red Top subunit which had relatively high defoliation in 1982.

Tree Mortality and Top-kill

Pole and Sawtimber

Mortality and apparent top-kill of budworm host trees were measured again in 1982 (table 3). Although it appears that the trees per acre and basal areas have increased dramatically from 1981 to 1982, an ANOVA comparing the average number of trees per acre in 1981 and in 1982 for treated and untreated areas separately showed that there was no significant differences (table 4). Sampling error and differences in sampling technique contributed to the apparent difference.

The differences between apparent top-kill figures for each year show the subjectivity of determining apparent top-kill. An accurate estimate of western spruce budworm-induced top-kill cannot be made until 1 or 2 years after the infestation collapses. Statistical comparisons between treated and untreated areas cannot be made because selection of the areas was not random and stand parameters are not equal. However, general comparisons can be made. Top-kill of all host tree species (Douglas-fir and true firs) was greater in the untreated area than in the treated area in both 1981 and 1982. It thus appears that the carbaryl spray early in the infestation cycle in 1977 prevented permanent tree damages from occurring, so far.

Seedlings and Saplings

Mortality and top-kill of western spruce budworm host tree seedlings and saplings are shown in table 5. Total trees per acre for Douglas-fir, true firs, and total host trees in 1982 were less than the 1981 figures because of a different sampling technique. The cluster plots were established as stated in the methods section in 1977; however, somewhere between 1977 and 1981, the cluster plots were reestablished in a different manner. If the cardinal direction subplots did not have any seedlings or saplings, at 100 feet, the cluster plots were established either closer in or further out where seedlings and/or saplings occurred. Thus, the data reported as trees per acre were actually trees per acre of regeneration. In order to compare current mortality and top-kill to the 1977 base line, or "natural" mortality, the cardinal direction subplots were reestablished in 1982 at 100 feet from the central subplot.

Top-kill of host trees was greater in the untreated area than the treated area; 24.1 percent versus 2.0 percent. Mortality of host trees was basically equal to that in the treated area; 1.9 percent and 1.5 percent, respectively. These mortality levels cannot be ascribed to western spruce budworm, since many mortality factors are present and no determination of the cause of mortality was made. Also, these levels are much lower than the 1977 "natural" mortality figure.[2]

DISCUSSION

The increase in population levels in the treated area may be due to immigration, resident population buildup, or a combination of both. Immigration, however, appears unlikely since adjacent untreated areas also experienced large population increases at the same time, as shown by the increase in acres of defoliation detected by aerial survey[8] (figure 2).

There are two most likely scenarios for the outbreak in the Jemez Mountains. One is that the infestations will all collapse at the same time, in both treated and untreated areas. If this occurs within the next several years, permanent tree damages will have been averted in the treated area. Should the outbreak continue for a number of years before collapse, permanent tree damages should still be less in the treated area.

The second possible scenario is that infestations in the untreated areas collapse, but infestations in the treated area do not. Permanent tree damages will likely be similar in treated and untreated areas should this occur. The treated area infestation may collapse sometime after the infestations in the untreated areas collapse in the Jemez Mountains. Another possibility is the outbreak could continue by shifting back and forth between the treated and untreated areas. This shift could be due to immigration, alternating periods of resident population fluctuation due to changes in stand conditions, or both.

This outbreak will be monitored to observe what does occur and what impacts result.

FUTURE PLANS

A detailed plan for sampling during the rest of the infestation is being prepared. The western spruce budworm population will be monitored and impacts periodically assessed. After the infestation collapses, an assessment of the impact of the infestation and the treatment will be made.

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[8] Telfer, W. G. 1982. Biological evaluation, western spruce budworm, Santa Fe National Forest, Jemez Indian Pueblo, and Santa Clara Indian Pueblo, NM. USDA Forest Serv. Southwestern Reg. R-3 83-3. 21 pp.

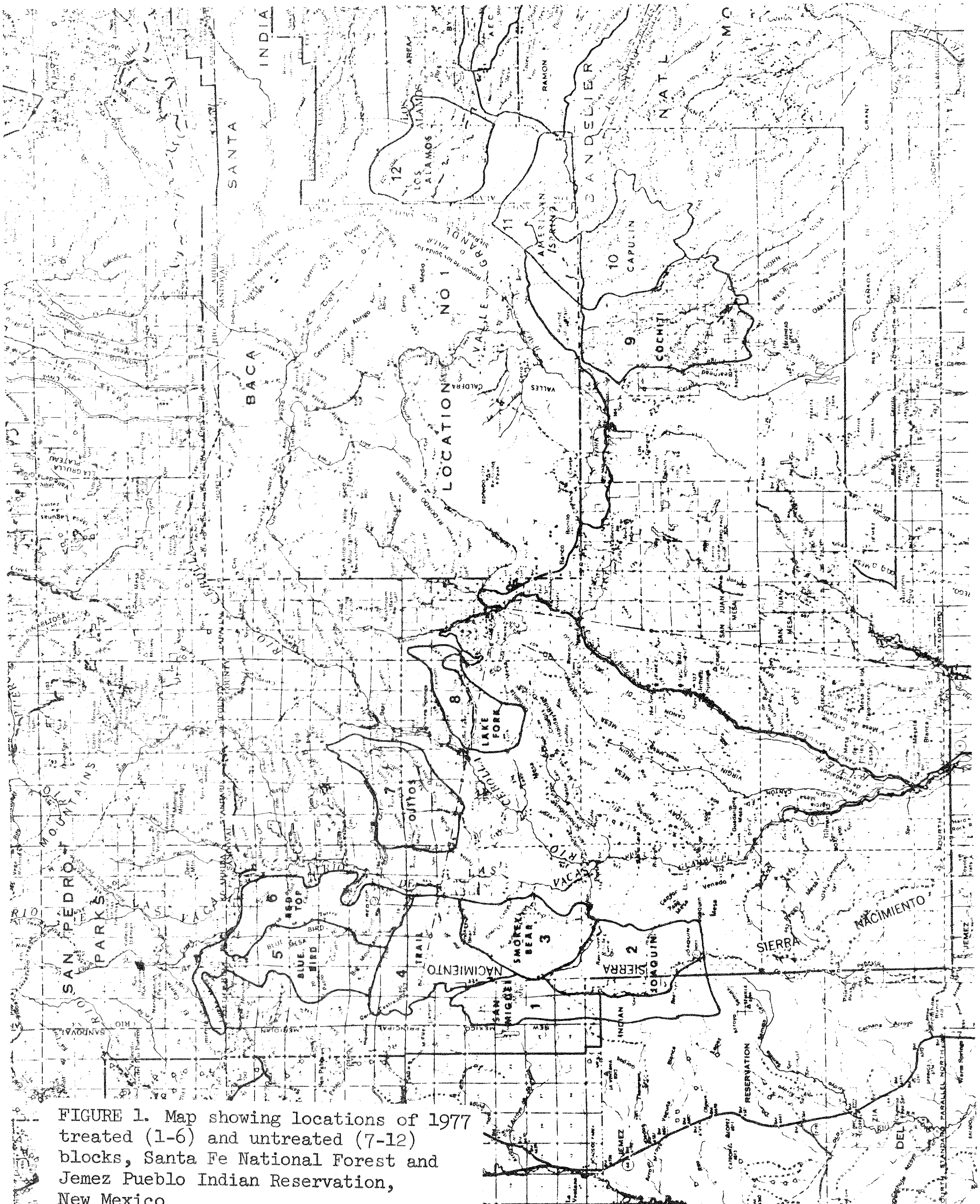

FIGURE 1. Map showing locations of 1977 treated (1-6) and untreated (7-12) blocks, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico

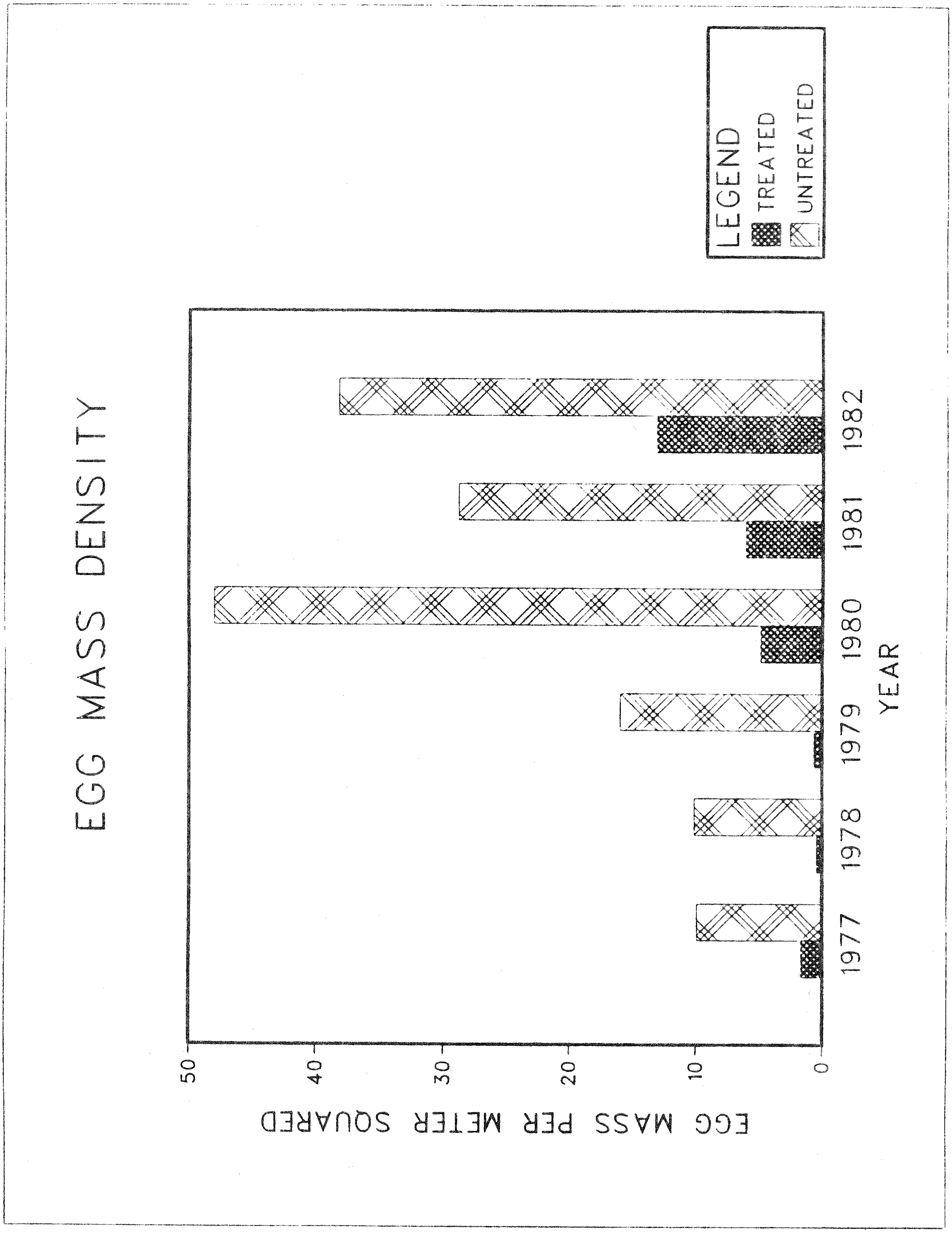

FIGURE 2. Comparison of average number of western spruce budworm egg masses in treated and untreated areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico

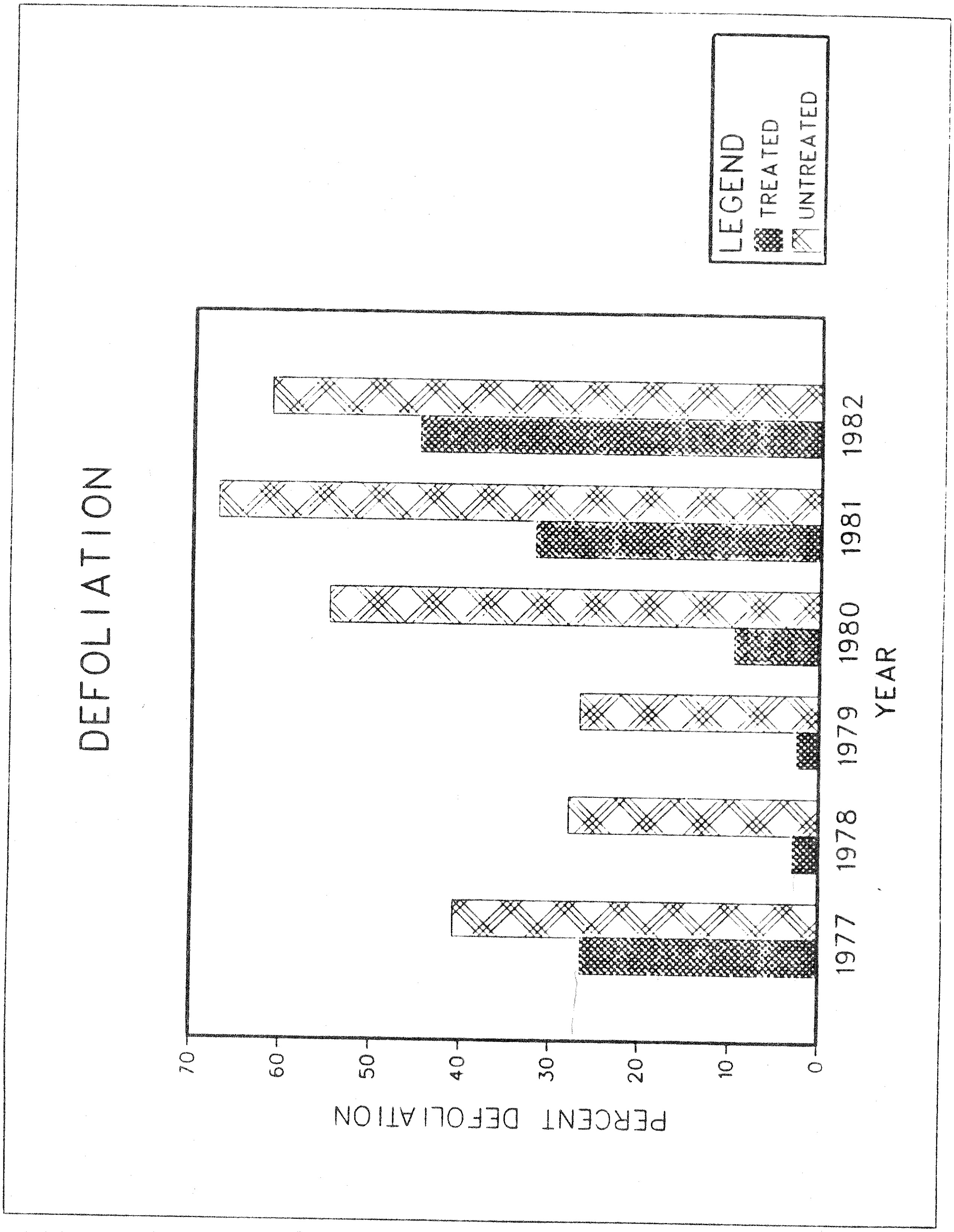

FIGURE 3. Comparison of average western spruce budworm-caused defoliation of Douglas-fir in treated and untreated areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico

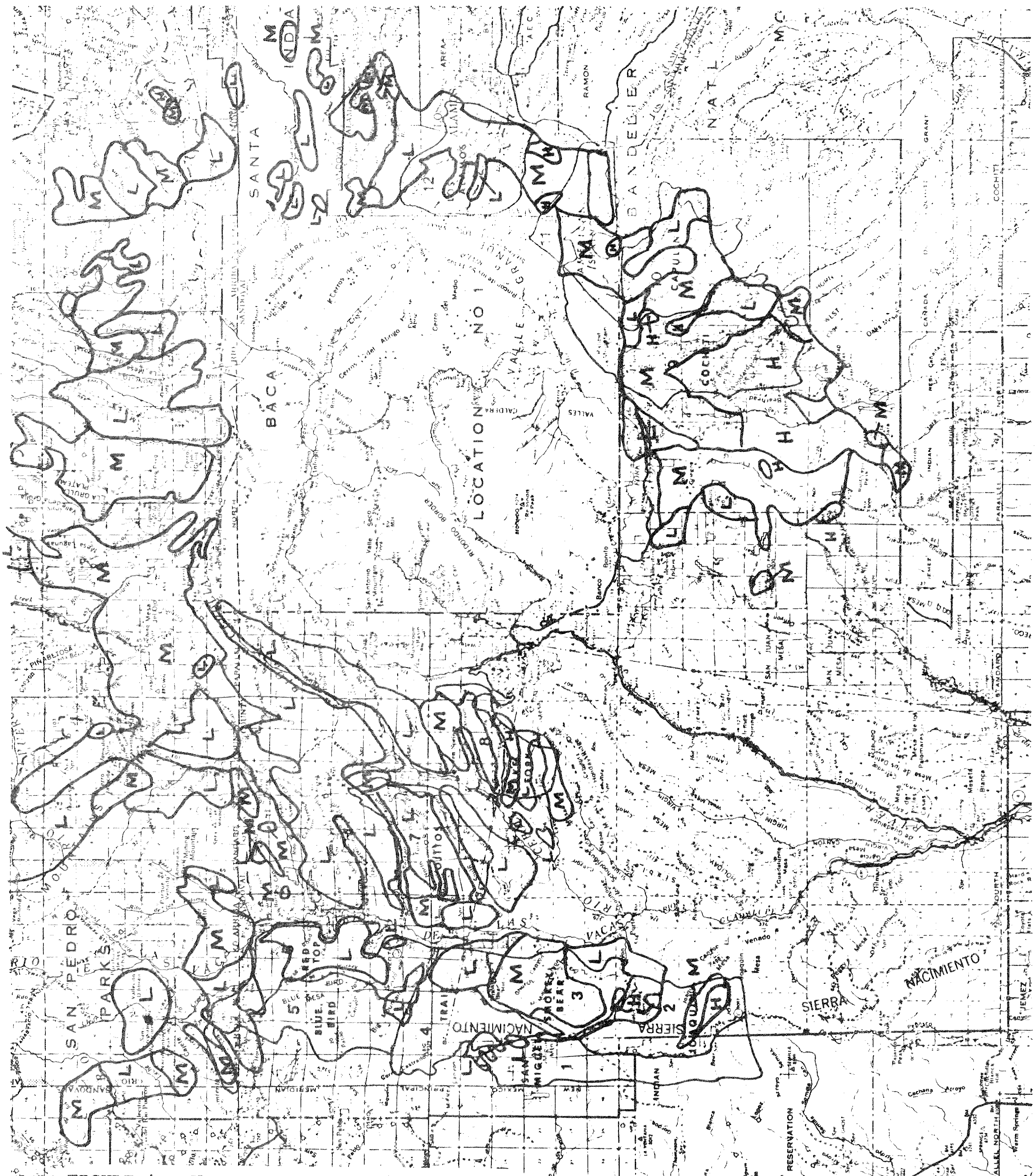

FIGURE 4. Western spruce budworm defoliation detected by aerial surveys in 1982, Jemez Mountains, Santa Fe National Forest, New Mexico

TABLE 1. Western spruce budworm egg mass densities on treated (1-6) and untreated (7-12) check subunits, Santa Fe National Forest and Jemez Pueblo Indian Reservation lands, New Mexico

Treated subunits	Egg masses per m^2 of foliage											
	1977		1978		1979		1980		1981		1982	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1. San Miguel	4.2	1.1	0.9	0.3	0.7	0.3	3.4	1.1	4.4	1.6	14.7	5.0
2. Joaquin	1.4	0.5	0.0	0.0	0.2	0.1	6.4	1.8	5.9	1.2	20.7	3.6
3. Smokey Bear	0.2	0.1	0.2	0.1	0.4	0.2	3.5	0.7	3.9	0.9	9.9	1.9
4. Trail	1.9	0.6	0.6	0.2	1.2	0.4	7.6	4.0	5.4	2.4	13.3	5.8
5. Blue Bird	1.2.	0.4	0.4	0.2	0.8	0.3	5.7	4.7	4.6	1.5	7.7	2.9
6. Red Top	1.0	0.3	0.5	0.2	0.6	0.3	2.8	0.7	12.4	3.1	12.5	1.82
Average	1.7[a]*		0.4[a]		0.6[a]		4.9[b]		6.1[b]		13.1[c]	1.82
Untreated subunits												
7. Ojitos	1.0	0.3	1.0	0.3	1.5	0.6	14.9	6.0	14.1	2.6	33.0	8.1
8. Lake Fork	7.5	1.7	11.2	2.6	17.9	3.7	39.6	11.0	37.2	7.7	38.3	6.4
9. Cochiti	11.6	2.9	12.4	2.5	21.0	5.2	69.7	9.0	37.4	7.8	46.1	5.9
10. Capulin	14.4	2.5	12.5	1.9	19.2	3.3	51.7	9.2	32.6	5.4	60.5	7.1
11. American Springs	7.4	1.1	11.1	1.7	15.0	2.8	60.1	8.9	22.4	3.1	23.0	3.7
12. Los Alamos	17.5	2.6	12.5	1.9	20.6	3.2	51.9	6.6	29.1	3.7	28.2	3.8
Average	9.9[a]		10.1[a]		15.9[ab]		48.0[c]		28.8[b]		38.2[bc]	5.5

* Figures followed by different letters are significantly different at the 0.05 level using a Newman-Keuls test (i.e., a is significantly different from b and c, etc.).

TABLE 2. Percent defoliation of Douglas-fir treated (1-6) and untreated subunits, Santa Fe National Forest and Jemez Pueblo Indian Reservation lands, New Mexico

Subunits	Percent defoliation					
Treated	1977	1978	1979	1980	1981	1982
1. San Miguel	41.6	4.5	3.7	9.2	25.5	27.3 ± 6.3[1]
2. Joaquin	19.9	1.5	2.0	7.1	51.9	56.0 ± 6.6
3. Smokey Bear	18.0	1.1	1.0	7.6	31.5	53.0 ± 5.8
4. Trail	37.0	5.4	2.2	12.5	25.3	34.0 ± 5.4
5. Blue Bird	25.5	2.7	3.0	13.6	23.6	33.4 ± 5.4
6. Red Top	16.6	2.0	3.2	8.1	33.6	65.5 ± 5.9
Average	26.5[a*]	2.9[b]	2.5[b]	9.6[b]	31.9[a]	44.9[c]
Untreated						
7. Ojitos	14.1	9.4	6.8	24.4	65.0	73.6 ± 7.1
8. Lake Fork	51.1	40.9	34.1	48.4	72.6	68.3 ± 4.3
9. Cochiti	37.2	35.3	29.4	55.4	71.8	57.9 ± 6.2
10. Capulin	51.2	29.0	28.3	65.7	61.0	52.6 ± 3.4
11. American Springs	34.2	29.1	31.6	73.5	65.4	58.2 ± 3.5
12. Los Alamos	56.7	23.8	29.9	60.9	67.2	57.2 ± 5.1
Average	40.8[ab]	27.9[a]	26.7[a]	54.7[bc]	67.2[c]	61.3[c]

* Figures followed by the same letter within treatment areas are not significantly different at the 0.05% level using a Newman-Keuls test.

[1] Standard error.

TABLE 3. Budworm host-tree pole and sawtimber mortality and apparent top-kill by trees per acre and basal area

	Treated				Untreated			
	Trees per acre		Basal area		Trees per acre		Basal Area	
	1981	1982	1981	1982	1981	1982	1981	1982
Douglas-fir								
Live	105.8 ± 18.58[1]	114.4 ± 18.45	51.4 ± 6.12	52.7 ± 5.87	58.6 ± 12.12	101.5 ± 11.71	32.7 ± 5.63	52.0 ± 5.39
Dead	0	0	0	0	0	0	0	0
Top-kill	1.8 ± 1.83	0	0.7 ± 0.67	0	14.0 ± 8.31	9.3 ± 4.43	8.0 ± 3.91	3.4 ± 1.38
Total	107.6	114.4	52.1	52.7	72.6	110.8	40.7	55.4
True fir								
Live	32.8 ± 9.40	53.8 ± 16.64	22.7 ± 5.32	28.7 ± 6.34	33.9 ± 11.54	30.8 ± 9.70	19.4 ± 5.29	20.7 ± 4.84
Dead	0.4 ± 0.41	0	0.7 ± 0.67	0	0	1.2 ± 1.17	0	0.7 ± 0.67
Top-kill	4.6 ± 3.65	0	1.4 ± 0.93	0	1.4 ± 1.38	19.3 ± 7.76	0.7 ± 0.67	7.4 ± 2.62
Total	37.8	53.8	24.8	28.7	35.3	51.3	20.1	28.8
Total host								
Live	138.6	168.2 ± 28.17	74.1	81.3 ± 9.19	92.5	132.3	52.1	72.7
Dead	0.4	0	0.7	0	0	1.2	0	0.7
Top-kill	6.4	0	2.1	0	15.4	28.6	8.7	10.8
Total	145.4 ± 23.35	168.2 ± 28.17	76.9 ± 8.69	81.3 ± 9.19	107.9 ± 15.06	162.1 ± 16.86	60.7 ± 7.08	84.0 ± 7.20
Nonhost								
Spruce	6.4 ± 3.13	9.7 ± 4.89	4.0 ± 1.77	5.4 ± 2.34	0	1.9 ± 1.91	0	6.7 ± 0.67
Ponderosa pine	16.8 ± 6.61	18.4 ± 7.76	13.4 ± 4.73	13.4 ± 4.73	24.1 ± 6.84	29.8 ± 8.98	16.7 ± 3.84	20.7 ± 4.84
Total	23.2	28.1	17.4	18.8	24.1	31.7	16.7	21.4
Total Trees	168.6	196.3	94.3	100.1	132.0	193.8	77.4	105.4

1 Standard error.

TABLE 4. One-way ANOVA comparing the average number of trees per acre of poles and sawtimber by diameter class in 1981 and 1982 within the treated and untreated areas

Treated Area

H_0: No significant difference between 1981 and 1982.

Source	df	SS	MS	F	$F_{0.05}$
Groups	1	24.342	24.342	0.329	4.10
Within	37	2,740.692	74.073		

Conclusion: Hypothesis is accepted; no difference between 1981 and 1982.

Untreated Area

H_0: No significant difference between 1981 and 1982.

Source	df	SS	MS	F	$F_{0.05}$
Groups	1	5.249	5.429	0.52	4.04
Within	48	1,943.417	40.488		

Conclusion: Hypothesis is accepted; no difference between 1981 and 1982.

TABLE 5. 1982 seedling and sapling data by trees per acre, Santa Fe National Forest

	Trees per acre			
	Treated		Untreated	
	1981	1982	1981	1982
Douglas-fir				
Live	151.1 ± 20.76[1]	97.34 ± 14.68	258.0 ± 27.53	204.00 ± 26.85
Dead	5.9 ± 2.04	1.34 ± 0.94	3.3 ± 1.75	4.00 ± 2.09
Top-kill	9.6 ± 2.55	3.34 ± 1.75	23.3 ± 6.09	53.34 ± 11.42
Total	166.6	102.02	284.6	261.34
True fir				
Live	175.5 ± 33.59	166.67 ± 31.11	530.0 ± 131.61	246.00 ± 45.80
Dead	7.4 ± 3.09	2.76 ± 1.62	14.7 ± 4.57	4.76 ± 1.97
Top-kill	19.2 ± 7.32	2.00 ± 1.15	39.3 ± 7.38	55.34 ± 11.29
Total	202.97	171.34	584.01	306.01
Total host trees				
Live	326.6	264.01	788.0	450.00
Dead	14.1	4.01	18.0	8.67
Top-kill	28.9	5.34	62.7	108.58
Total	369.6	273.36	868.7	567.25
Nonhost				
Green spruce	11.1 ± 5.73	10.67 ± 4.25	27.4 ± 12.11	21.34 ± 8.00
Ponderosa	25.2 ± 5.92	16.67 ± 5.22	140.0 ± 23.89	97.34 ± 19.93
Total	36.3	27.34	167.4	118.58
Total number of trees per acre	405.9	300.70	1036.1	685.93

[1] Standard error.